Voluntary approaches, market structure and competition

by

Rinaldo Brau* and Carlo Carraro**

Abstract

This paper surveys the recent literature devoted to the analysis of the interactions between the adoption of voluntary or negotiated agreement as a tool of environmental policy and market structure. The goal of this survey is twofold. On the one hand, we would like to identify the market environment which is most favourable to the adoption of voluntary approaches, namely whether these are more likely to be signed within industries that are more or less concentrated. On the other hand, we aim at assessing the effects of voluntary approaches on market structure and industry concentration. Our findings suggest that the signature of voluntary approaches is favoured by a situation in which industry is more concentrated. Moreover, the adoption of voluntary approaches is likely to further increase industry concentration. This clearly raises a trade-off between environmental benefits and economic costs provided by the adoption of voluntary approaches that must be dealt with an appropriate policy-mix.

* University of Pavia and Fondazione ENI E. Mattei
** University of Venice and Fondazione ENI E. Mattei

The authors are grateful to Francois Lévèque, Marc De Clercq, Francesca Moriconi, Jane Wallace Jones and all participants in the CAVA concerted action for helpful comments and suggestions. CAVA is the European Research Network on Voluntary Approaches for Environmental Protection. It aims at achieving synergies between researchers and providing an efficient interface for policy makers. CAVA is steered by University College Dublin (Ireland), University of Gent (Belgium), Fondazione ENI Enrico Mattei (Italy), Öko-Institut (Germany), AKF (Denmark) and CERNA at the Ecole des Mines de Paris (France, Coordinator). The Network is funded by DGXII of the European Commission. For more information about the CAVA Network please contact chidiak@cerna.ensmp.fr or go to the web-site:
http://www.ensmp.fr/Fr/CERNA/CERNA/Progeuropeens/CAVA/index.html.

November 1998. Revised: March 1999

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INTRODUCTION

Voluntary approaches (henceforth VAs) are often indicated as one of the most important and effective instruments through which environmental targets can be achieved. It is not the goal of this paper to discuss the merits of VAs and the environmental benefits that they provide.[1] We would rather focus on one particular aspect of their functioning, namely the relationship between VAs and market structure. This is important for two reasons:

- on the one hand, VAs have sometimes been criticised because they reduce market competition, either because they provide incentives for collusive behaviour among firms, or because they set up barriers to entry in the industry, or because their implementation tends to increase market concentration. Hence, an analysis of these issues can provide the regulator with information on competition policies that may be needed when VAs are adopted as an environmental policy tool. In particular, one may wonder whether the environmental benefits provided by VAs are offset by their negative implication for industry competition (and consequently for the consumers' surplus). And whether competition policies are sufficient to get rid of the costs without reducing the benefits;

- on the other hand, market structure is one of the most important factors which explain the possible emergence of VAs and which can help us to evaluate their effectiveness. In particular, are VAs more likely to be adopted in a more concentrated industry? And if so, why? If VAs can be implemented more easily in an imperfectly competitive market structure, does this imply a trade-off between the objectives of environmental and competition policies?

This paper has therefore three objectives:

(a) we would like to understand which factors favour the adoption of VAs as an instrument of environment policy and then single out market structure among these;
(b) we aim to analyse the non-environmental implications of VAs, in particular their implications for market structure.

[1] See the excellent surveys prepared by Börkey *et al.* (1998). Mazurek (1998).

Notice that this amounts to analysing a bi-directional causality relationship between VAs and market structure. This is why this paper is divided into two parts. Part I is devoted to the analysis of the effects of market structure on VAs. Part II will focus on the opposite causality direction, namely the impact that VAs may have on market structure. There is also another objective for this paper:

(c) we would like to derive some policy conclusions that may help policymakers to assess the economic trade-offs associated with the use of VAs.

If the adoption of VAs has a negative externality for industry competition, policymakers must be very careful when implementing this type of instrument and may decide to introduce appropriate controls and regulations.

The theoretical framework that will be used in this paper relies on oligopoly theory. There are at least two reasons which explain this choice. The first one is theoretical and has to do with the specific goal of this paper. If we aim at understanding how changes of industry concentration affect VAs and vice versa, we cannot assume a given level of concentration in a given market structure. This would be the case had we assumed the polar cases of perfect competition or monopoly. In order to analyse the variability of the number of firms and of industry concentration we need to focus on a market structure in which concentration is a relevant variable dimension. Oligopoly theory therefore provides the most adequate theoretical framework and the largest input in terms of research work already carried out in this field.

The second reason is empirical and has to do with the very nature of VAs. VAs can be seen as a specific policy instrument lying between direct regulation and economic instruments. The use of VAs, vis-à-vis other environmental policy instruments, can be justified in several cases. The most general case occurs when environmental protection is to be achieved through technological innovation. It is well known that standards, environmental taxes or emission permits are a sub-optimal instrument to achieve the adequate level of technological innovation.[2] Taxes may induce under- or over-investment, as well as undesirable distortionary effects. For example, Laffont-Tirole (1994) show that, in a dynamic framework, taxes or permits may induce firms to over-invest in environmental innovation in order to by-pass the fiscal burden. Similarly, VAs are also optimal when environmental innovation has positive spillovers on other firms, which need to be internalised in order to avoid underinvestment or delayed adoption (D'Aspremont-

[2] A detailed discussion of this statement with reference to environmental protection is provided in Carraro-Siniscalco (1994) and in Carraro-Lanza-Tudini (1994).

Jacquemin, 1988; Musu, 1994; Carraro-Topa, 1994). In such cases, the government needs two instruments to correct two externalities: one related to pollution and one to innovation.[3]

Therefore, VAs play an important role in stimulating environmental friendly innovation in the presence of market failures and imperfect competition. Still in a sub-optimal world, VAs should be used to reduce pollution in strategic industries that produce tradable goods. Consider a polluting industry in an open economy, which cannot be decommissioned for strategic reasons. The domestic government unilaterally implements a policy of industrial pollution control, by inducing innovation through firm-specific costly investment. Under imperfectly competitive market structures, international competition leads the national government to induce innovation through VAs, with a subsidy that varies according to market structure (Carraro-Siniscalco, 1992). Other effective instruments, such as command and control, permits, taxes, distort competition and may dramatically reduce profits. The same argument, which becomes even stronger in the presence of global externalities, can be applied to regional policy.

All the above examples have one common denominator: inefficiency, market failures, strategic behaviours are strictly related to imperfect competition in the product market that can be effectively captured by an oligopolistic theoretical framework.

Hence, the next sections will focus on an oligopolistic market structure where VAs are proposed to achieve a given environmental target. As said, Part I will discuss whether in a more concentrated oligopolistic market VAs are more likely to be signed and what is the effectiveness of VAs in this context. Part II will analyse the possible impacts of VAs on the strategic behaviours of oligopolistic firms, and the related impacts on competition and industry concentration. A final section will summarise the policy implications of the analysis and will analyse the relevance of a likely trade-off between the goals of VAs and of competition policies.

[3] This case, however, requires the development of a framework with one principal and many interdependent agents, which involves considerable analytical complications (see Demski-Sappington, 1983; Ma-Moore-Turnball, 1988; Laffont-Tirole, 1993). But this would not add very much to the intuition.

Part 1: Effects of market structure on VAs

1.1. Strategic Incentives in Oligopoly and VAs.

Let us start this part of the paper by providing some definitions and by describing in more detail the theoretical framework that will be used. Following the presently more widespread definition, by the term "voluntary approaches" we refer to "commitments from polluting firms or industrial sectors to improve their environmental performance" (Lévêque, 1997). They can be placed into three main categories: *unilateral commitments*, which consist of environmental improvement programmes established by firms themselves and communicated to their stakeholders; *public voluntary schemes,* in which participating firms agree to standards developed by public bodies such as environmental agencies; *negotiated agreements,* which are contracts between the public (national, federal or regional) authorities and industry.

As said in the Introduction, firms are assumed to compete in an oligopolistic industry; in this framework, firms determine a set of strategies, including VAs, that help them to maximise profits. What are the reasons for which profit maximising firms decide to sign VAs?

Most existing studies have underlined two possible explanations:

- VAs can increase market demand and therefore profits by *enhancing firms' green reputation.* VAs therefore becomes a product differentiation strategy that helps to create niche markets and/or help to identify a firm's products. Notice that this explanation of why firms adopt VAs relies on the possibility of differentiating products and is therefore valid only in the case of imperfect competition;
- VAs can be used to achieve *regulatory gains*. In this case, the profit coincides with the avoided costs of public regulation aimed at addressing the environmental problem. [4]

This distinction between *reputation enhancing VAs* and *regulation offsetting VAs* will be largely used in the next sections to understand how market structure affects VAs and their likelihood of being used as environmental policy tools. Notice that the *input savings VAs* (Börkey *et al.,* 1998), i.e. VAs which achieve both additional pollution abatement and at the same time allow a firm a better use of and access to inputs,

[4] Studies refer to these aspects in a number of ways, for example 'green consumerism' or 'pre-emption of public regulation'. Here we adopt the same taxonomy used by Glachant-Lévêque (1998).

will not be specifically dealt with here. The reason is that we focus on cases in which VAs have a negative impact on production costs, i.e. it is costly for the firm to voluntarily abate pollution levels.

It is also important to stress that VAs are not only seen as strategic variables in the hands of firms, but also as environmental policy instruments. From this viewpoint, they provide environmental benefits with which other social costs and benefits can be associated. Provided that the environmental goal is attained, benefits from using VAs can arise in a number of ways. For example, in terms of reduced public costs (whether monitoring or transaction costs), diminished implementation time or greater learning. Further benefits can emerge from the higher quality of commodities.

Social costs related to VAs are usually measured in terms of reduced consumer's surplus and lower firm profits. In most papers, the government is assumed to maximise a social welfare function when setting its optimal environmental policy. This welfare function is usually defined as the sum of consumer's surplus, firms' profits and environmental benefits. It is therefore crucial to check whether the adoption of VAs actually maximises social welfare. Suppose profits are maximised (otherwise firms would not sign a VA). What are the impact on environmental benefits? If VAs are aimed at pre-empting regulatory interventions and merely commit signatories to 'business-as-usual' objectives, then environmental benefits could be lowered by the adoption of VAs. What is the effect on the consumer's surplus? If VAs lead to an increased industry concentration, the consumer's surplus could also be lowered. The final outcome could be a reduced level of social welfare *vis à vis* other environmental policy tools.

Of course, the conclusion could well be the opposite one. If VAs, as said in the Introduction, enable the adoption of an environment-friendly technology at a minimum cost for firms, the achieved environmental benefits can be larger and the economic costs lower, thus increasing social welfare with respect to other instruments (despite a possible reduction of the consumer's surplus).

Hence, the goal of Part I of this paper is not only to identify the strategic incentives that firms have to sign VAs, but also the consequent social benefits and costs and the possible trade-offs between different government objectives.

The next two sections will analyse VAs from a firm's viewpoint, thus focusing on reputation enhancing mechanisms and regulatory gains. The last section of Part I will instead deal with the government's viewpoint and will analyse how VAs affect different components of social welfare.

1.2. The Green Reputation Enhancing Factor

A first group of papers that analyse the impact of market structure on VAs share the characteristic of assuming that strategic interaction between firms is aimed at capturing consumers' willingness to pay for the environmental attributes of goods. In other words, either firms exploit the increasing demand for green products and/or firms differentiate their products or processes in order to increase their own market demand *vis à vis* their competitors. A first basic assumption of these models is therefore that consumers give a positive value to environment-friendly products or processes and that this value is reflected in their demand for goods.

An empirical support for this assumption is provided by Arora-Gangopadhyay (1995) which refer to a survey by a British product-development–consultancy in 1989 which revealed that 53% of people questioned had declined to buy a product because they were worried about the effects of the product or its packaging on the environment. Furthermore, about 75% of the people surveyed were willing to pay more for products which were degradable and had recyclable packaging.[5]

Further evidence is provided by a voluntary program like 33/50, which is a public voluntary pollution reduction program founded on the green reputation enhancing factor. This program was initiated by the EPA in 1991 and invited approximately 5,500 companies (although only approximately 1,300 companies actually participated in the initiative. Cf. Mazurek, 1998) to voluntarily reduce the release and transfer of 17 target chemicals by 33% by 1992 and by 50% by 1995 through the use of pollution prevention technologies. The program's progress has been monitored by the interpretation of data on the publicly available Toxic Release Inventory (TRI) which records all manufacturing establishments' release and transfer of over 320 toxic chemicals. The key to the functioning of the program appears to be that the companies which decide to participate in the 33/50 program are given incentives such as public recognition by the EPA, special awards for outstanding achievement in pollution prevention as well as the opportunity to take least cost actions to mitigate pollution ((Arora-Cason, 1994a,b).[6]

[5] Surveys are often used in evaluating environmental quality improvements. Bartolomeo-Hafkamp (1998) discuss a study on the additional willingness to pay for greener electricity in US.

[6] However, it has been questioned as to whether it is the anticipation of pressure from the general public which leads companies to alter their behaviour in this case, given that the average citizen may not even be aware of the TRI's existence. It could actually be the case of an anticipation by other stakeholders or regulators intervention. The two authors conclude their empirical assessment of the program by suggesting that the EPA can, in fact, achieve significant results with this and other similar information-based voluntary programs by encouraging competition in environmental quality.

Let us see how a firm's environmental performance affects market demand. There are three main effects that we would like to highlight:

- market demand upward shift
- market demand increased slope
- product differentiation.

The first two effects concern industry market demand, whereas the third effect is directly related to a specific firm's demand.

The first effect is easy to understand. If consumers value a clean environment in their utility function, they are ready to pay a higher price for "clean" products or processes, i.e. non-polluting products or products produced using environment-friendly technologies. Hence, market demand shifts upward when "clean" products are sold in the market. This increases firms' profits, thus providing an incentive for firms to voluntarily carry out emission abatement policies that can be framed within a VA with the regulator. Consumers are also generally better off if they can enjoy the better environment that they are ready to pay for.

However, as Carraro-Soubeyran (1996b) showed, if consumers care about the environment, then the demand curve is also steeper for any output level. This is what we call the "market demand increased slope" effect. Hence, in the presence of "green consumerism", firms can increase their market prices without suffering excessive demand reductions. In other words, firms face a less elastic demand function and therefore increase their market power.

The consequence is that firms' profits can increase, but higher prices may reduce the consumers' surplus, in particular if some collusion occurs, thus partly offsetting the environmental benefit achieved through the VA. This is a first example of the trade-off between different government objectives that the implementation of VAs may imply.

Firms can also try to increase profits by differentiating their product or process from those of the other firms in the industry. This is the third effect, and it differs from the other ones because it is a relative effect that benefits only a subgroup of firms. In this case, consumer's surplus may not be reduced, whereas profits and environmental benefits may increase. The next two sections will be devoted to analysing whether and under what conditions this socially optimal situation occurs.

1.2.1. Green reputation enhancing VAs.

Let us first consider a model in which consumers' environmental preferences affect market demand, but firms produce a homogeneous good. In the next section, we will focus, instead, on product differentiation. For the sake of simplicity, consumer preferences are assumed to be separable into income and environmental characteristics, and the marginal utility of money is assumed to be constant and equal to 1. In other words, the effect of environmental damage on the consumer's utility function remains the same, whatever the consumer's income or the amount of goods consumed by the individual. Let us also assume that consumers only perceive part of the total environmental damage.

Social welfare is defined by taking into account gross consumer's surplus, the share of environmental damage not considered by consumers, industry production and abatement costs. Profits are not explicitly considered in the social welfare function.

Finally, all firms are assumed to be identical and to use both their production level and their emission level as strategic variables. The reason is that both the quantity produced and the related emissions affect market price. This is a consequence of having assumed that environmental quality enters a consumer's utility function.

Using this framework, Garvie (1997) shows that:

- *The optimal firms' effort to reduce emissions is equal to zero only if consumers do not value at all in their utility function the environmental damage caused by the production of the good. If sensitivity to pollution is present to some extent, then it is optimal for firms to abate.*[7]
- *If consumers have partial awareness of environmental damage, firms' abatement is sub-optimal with respect to the socially optimal abatement level (the one determined by the government by maximising social welfare).*

[7] Empirical evidence on the role of consumers' awareness on firms' environmental performance has been found by Tietenberg (1997) and by Borghini *et al.* (1998). A direct policy implication is that policy makers should encourage adoption of environmental information systems (Darrell *et al.*, 1997; Lanoie *et al.*, 1997).

- *Firms strategies are strategic complements with respect to abatement efforts (the best response functions are positively sloped); in words, the more one firm reduces emissions, the more the others have an incentive to do the same.*[8]
- *Market structure affects social welfare. Due to the free riding mechanism, a larger number of firms implies a lower level of the total abatement effort.*
- *The number of firms and the consumers' sensitivity to the environmental damage jointly determine a critical level which makes it convenient for firms to undertake voluntary abatement.*
- *A higher level of welfare can be achieved if firms are allowed to cooperate in their emission strategies (e.g. through an industrial association which determines a voluntary abatement code for all firms in the industry).*

This last result is particularly interesting because it shows that a more concentrated industry, where co-ordination among firms can be achieved more easily, can provide a higher abatement level and an increased social welfare. It parallels the other result, whereby a larger number of firms implies a lower level of the total abatement effort because of free riding, which also supports the conclusion that VAs are more effective and more easily achieved in more concentrated industries.[9]

As a consequence, if a regulator wants to use VAs to achieve his environmental objectives, he may decide to allow firms to merge or to collude, thus increasing concentration and creating an environment in which VAs are more likely to be adopted.

Notice that the conclusion is quite different if a standard economic instrument, e.g. an environmental tax, is adopted. Indeed, when markets are oligopolistic, an environmental tax is a second best instrument and its optimal value is below the marginal social damage (Katsoulacos-Xepapadeas, 1996). A tentative conclusion would therefore be that:

taxes are to be preferred when markets are (nearly) perfectly competitive, whereas VAs are better policy tools when markets are oligopolistic and fairly concentrated.

[8] Best response functions (or reaction functions) express the optimal choice (control) variable of a firm as a function of the value of such a variable chosen by the other firms. If the optimal value of the variable x for firm i is increasing with the value chosen by firm j, firms' actions are said to be "strategic complements"; if the opposite is true, they are defined as "strategic substitutes".

[9] This hypothesis has been successfully tested by Cunningham *et al.* (1998) with respect to the use of VAs in Ireland.

A deeper analysis of these issues will be carried out in the next section.

1.2.2. Quality differentiation and voluntary overcompliance

In the previous model, all firms produce the same homogenous good. Hence, the model cannot capture an important dimension of the *reputation enhancing factor*, namely the incentive for firms to exploit consumers' preferences for the environment in order to increase their own market demand and market share. This can be done by differentiating their products with respect to those offered by competitors, thus creating a niche market where a higher market price can be imposed.

The usual Hotelling's model of product differentiation can be applied to analyse firms' green differentiation strategies. Assume that market is segmented because consumers display a different attitude towards "green" efforts by firms or "green" characteristics of products. Assume also that there are only two firms. As is usual in product differentiation models, interaction between the two firms is modelled as a two-stage game. In the first stage, firms decide their product's relevant characteristic which is, in our case, the choice of emission technology (therefore we assume that the goods are homogeneous with regard to all other aspects). In the second stage they compete in prices.

Notice that the choice of emission levels is equivalent to the location choice in Hotelling's model. Hence, as well known from the work by D'Aspremont *et al.* (1986), if costs for consumers that cannot buy the most preferred product are non-linear, the firms' optimal choice is not to locate their production in the same location, i.e. it is optimal to differentiate. Similarly, when firms choose their emission technology it is optimal not to choose the same technology (Arora-Gangopadyay, 1995). Hence, there will be two types of firms in the market, one with high and the other one with low emissions per unit of output. The VA can be seen as the choice of firms to adopt positive, albeit different, abatement levels. As remarked in Cremer-Thisse (1994) however, in these standard vertical differentiation models the market will tend to under-provide environmental quality even in the absence of externalities or spillovers.

This model constitutes a useful starting point for another theoretical topic, i.e. how VAs perform if "command and control" and "economic" environmental policy tools are in place in the economy. The conclusion is that:

In a framework of heterogeneous tastes and product differentiation, the use of an effective minimum standard is recommended.

Intuitively, the worst firm wants to move as little as possible from its optimum and, as a consequence, will meet the standard exactly. In order to maintain product differentiation, the best firm will over-comply with the standard. In other words, when firm 2 chooses a higher emission control level then firm 1 also has an incentive to choose a higher level. This result, which amounts to saying that firms' strategies are strategic complements, was already found in the simple green reputation enhancing case examined in the previous section.[10] Therefore, a regulator can increase industry emission abatement by forcing the most polluting firm to reduce its emissions.

Consider now a VA when there is also an environmental tax. Arora-Gangopadyay (1995) show that the tax reduces firms abatement effort. If greater emission abatement is desired, the production of the good must be subsidised. With a subsidy, firm 2 can increase its clean-up effort at the same price, consequently taking away some of firm 1's customers (the poorest[11]). Firm 1 will react with an enhancement of its environmental performance.

In the case of tradable emission permits, the introduction of the VA modifies the traditional condition which states that permit trading will occur up to the point in which the marginal abatement costs of different firms are equalised to the price of the permit. In particular, being a net seller of permits has now become a way of reinforcing the clean image of the firm. In equilibrium, there will be fewer trades than predicted by the rule based on the equalisation of marginal costs.

These results help us to understand how a situation in which markets are oligopolistic and products are differentiated can actually favour the emergence of environmental VAs. In this setting, VAs become a strategic variable to achieve differentiation thus increasing profits. A regulator must again face a trade-off between the objective of fostering competition and the objective of protecting the environment at a minimum cost. Also note that the presence of VAs may reduce the effectiveness of other policy instruments, e.g. taxes or permits.

[10] A similar conclusion, albeit with a different model, is obtained by Luts, Lyon and Maxwell (1998).

[11] Heterogeneity of consumers' preferences in this model is obtained by introducing a positive relationship between sensitivity to environmental degradation and individual income level.

In this paper, we usually assume perfect information for all the agents. This assumption is likely to be stronger than usual when considering the case of unorganised consumers which are supposed to be able to identify the environmental quality of a good or of the process through which it is produced. If consumers are not able to distinguish between products of different quality levels, we should expect that some goods would be supplied in the market pretending to be "green" even if they actually are not.

As is well known from general economic theory, the problem of asymmetric information can lead to a complete market failure. Let us explain the mechanism in the case of imperfectly informed consumers characterised by green preferences. As in the previous section, on the supply side we have two types of firms, those willing to produce goods with lower environmental quality and those willing to offer greener (and costlier) goods through voluntary abatement. However, we now expect that the former, given that consumers are not able to distinguish among the intrinsic qualities of commodities, will state that their normal product is an environmental friendly one in order to capture the additional consumers' willingness to pay. On the demand side, rational consumers anticipate the attempt of cheating by bad firms and are no longer disposed to pay the price they would have paid had they been certain about the quality of the good. If the cost of abating emissions is sufficiently high, no green firms will be able to profitably enter the market and consumers will expect to buy only low quality goods, leading to the disappearance of the market for green products.

Since the seminal article by Akerlof (1970), who illustrated this market failure by referring to the market of used cars, a huge literature has studied and offered solutions to the asymmetric information problem.[12] When consumers can at least express a judgement on the environment quality of a product from a given period onwards,[13] a possible solution can arise from the fact that firms want to built a green reputation for their commodities. Indeed, by using a standard reputation model, Cavaliere (1999) shows that, in a framework of repeated interactions:

a) on the demand side, consumers will find it optimal

- to demand a low quality good if this was the good bought in the previous period;
- to randomise their choice between the two types of goods if they had acquired a green good one period before;

[12] A basic reference for this literature is the book by Laffont-Tirole (1993).

[13] Two cases can ensure this condition to be effective: a) we are in the presence of an "experience good", that is individuals are able to infer the environmental quality of a good when consuming it; b) environmental quality becomes "common knowledge" once a defined voluntary agreement is undertaken.

b) on the supply side, by considering a firm which can display different exogenous "types" which make it more or less willing to voluntarily abate,[14]

- the greener firm type will find it optimal to produce a high quality good in every period;
- the other firm type will find it optimal to produce a green good in at least the first period.

This self-enforcing market failure solution has two drawbacks. On the one hand, it allows for "one shot" voluntary abatement (while it could seem more likely that emission reduction requires a permanent investment). On the other hand, an assumption of awareness of the quality of the good is needed. Indeed, we can also envisage a situation in which consumers cannot directly discover the "green" nature of the goods they consume. At least two families of models can provide us with some insights for this extreme case: models of "screening" and models of "signalling."

Kuhn (1999) offers an example of the former by discussing a case of a public agency which can optimally design a series of requirements to be satisfied by firms in exchange for the award of an "ecolabel". In this case, what the public agency (the principal) is aiming at is a "separated equilibrium", in which the "green" and the "bad" firm (the agents) reveal their nature by voluntarily choosing different remuneration schemes, in contrast with a "pooling equilibrium" in which both agents choose the same offer by the principal.

With reference to the study of VAs, signalling models are more interesting. In these models, firms undertake a voluntary action in order to signal their environment-friendly nature to consumers. By considering the case of a monopolistic firm, Crampes-Ibanez (1996) find no strong results regarding to the nature of equilibria which arise in this case, both separating and pooling equilibria being possible. Useful insights would probably arise by allowing for a multifirm case with possibility of entry and strategic interaction.

1.3 Regulatory gains

As stated in the Introduction, there is a second basic incentive for profit-maximising firm to undertake a voluntary action to reduce or control polluting emissions. This second incentive was identified as the gain arising from the avoided costs of environmental regulation. In other words, firms, by signing a VA, avoid or postpone the introduction of a regulation that would have been more costly for firms than the costs of the VA.

[14] As a matter of fact, Cavaliere (1999) considers the case of a monopolist which can be exogenously less or more suitable to undertake a VA. This fact is private information, so that consumers do not know what type of firm they are facing.

Regulatory gains are usually considered to be the strongest incentive which induces firms to voluntarily undertake reduction of their pollutant emissions. Empirical support for this statement is provided by Maxwell *et al.* (1998).[15] By using a panel set of data on toxic chemicals releases in the U.S. from 1987 to 1992, they found that States with proportionally higher estimated membership in conservation groups (interpreted as a key variable in affecting regulatory threats) display a lower level of toxic releases. In another study, Darrell *et al.* (1997) find statistically significant differences in the quantity and quality of environmental disclosure in 53 corporate annual reports in the years 1988, 1989 and 1990 (post Exxon Valdez) in response to public policy pressure. As far as Europe is concerned, the recent Danish experience of a combination of CO_2 taxes with agreement schemes seems to have had some effect in making energy efficiency as a priority in company agendas (Johannsen-Togeby, 1998). Stronger quantitative evidence which supports the pre-emptive interpretation of VAs comes from the assessment of CO_2 reduction programs carried out in the Netherlands (Rietbergen *et al.* 1998)

When enlarging the analysis to the broad range of cases in which the firm reacts to public policies, a problem can emerge in the definition of what really constitutes a VA. In fact, a proportion of the situations in which firms adopt a pre-emption strategy cannot be considered truly voluntary, so that the border between what is voluntary and what is compulsory sometimes becomes fuzzy.[16]

Below, we will usually work under the assumption that, by reducing emissions through a voluntary action, firms can reach a given objective with lower costs than in the case when they are forced to satisfy a compulsory standard (Börkey *et al.*, 1998).

But we will also consider situations in which a well chosen abatement level can definitively pre-empt a regulatory intervention that would have imposed a tighter standard, so that the environmental target is actually lower under the voluntary approach regime. We can see this hypothesis as the extreme of a situation where carrying out a legislative action is costly and the benefits offered by the agreement are always greater than the fixed costs implied by the legal intervention. If that is the case, the results in terms of the implementation of the VA's effectiveness of course appear to be more problematic, given that a small voluntary abatement effort may pre-empt a strict compulsory requirement.

[15] See also Maxwell and Lyon (1998).

[16] A few models deal with the pre-emption issue in the case of price regulation. See Braeutigam-Quirk (1984), Lyon (1991) and Glazer-McMillan (1992).

The situation just described may occur when the public institution charged with signing a VA (e.g. the regulator) has a private agenda to satisfy which does not coincide with the objective of the institution (e.g. the legislator) charged with implementing other environmental policies. In this case, to sign a VA is, first of all, a "shortcut" to satisfying the regulator's interests and firms may be able to sign a VA which is less stringent than an truly effective environmental policy.

In the sequel we will discuss all these cases by distinguishing between two main types of models:

- models where firms use VAs to pre-empt a more stringent regulation that they cannot influence;
- models in which firms can also influence the regulatory threat, i.e. in which regulatory capture is also considered.

1.3.1 Negotiated agreements in the presence of a regulatory threat

In order to analyse the different aspects of firms' behaviour in the presence of a regulatory threat, we start by presenting a simple basic model, first introduced by Segerson-Miceli (1997)[17]. In this model, the regulatory threat is constituted by a mandatory regulation. However, the key point of this model is represented by the lower costs faced by the firm when it undertakes a voluntary abatement program, with respect to the case in which regulation is enforced Hence, the results can be applied whatever the regulatory threat, therefore including taxation schemes, and even in the presence of uncertainty about future regulations. We will use this model as a basic theoretical framework, which will be then extended in several ways, and which provides a useful tool to answer our basic questions on the relationships between VAs and market structure.

1.3.1.a A basic theoretical model

Let us assume that there exists a benevolent and perfectly informed regulator who is entitled to bargain over the level of emission abatement by the firm, while being subject to the constraint of maximising social welfare. A negotiated agreement is "a good thing" for the society because it is assumed that transaction costs for the public side are lower under the voluntary regime, and because the establishment of a

[17] We will make use of both the working paper version of this work, where the multi-firm case is also discussed, and of the published version (Segerson-Miceli, 1998) in which that part has not being included but additional considerations on the use of subsidies have been introduced.

mandatory standard is conditional on the uncertain intervention by a legislative assembly. The agreement is potentially profitable for the firm as well, because it can pre-empt the legislative standard and because the hypothesis of lower transaction costs is also made for industry. Hence, on the whole, unitary costs of pollution reduction are lower when an agreement is signed.

The main, albeit not surprising, result that can be derived from this model, is that:

> *at the equilibrium, there exists an interval of abatement levels for which a negotiated agreement is signed, provided that a regulatory threat (even weak) is anticipated by the firms.*

Hence, both parties find it optimal to adopt the voluntary agreement approach rather than the usual command and control approach. A short formal presentation of the model is given in Box 1.

This basic model can be extended in several ways. For example, it is possible to assume that the level of the threat is a variable which is not controlled by the regulator. The same can be done with respect to the firm's costs in the case of legislative regulation.

The regulator could, instead, affect the interval in which an agreement can take place by acting on firm's costs under the voluntary regime. In Segerson-Miceli (1998) it is shown that:

- *a subsidy to firms that accept to sign the agreement allows enlargement of the interval in which an agreement is possible and desirable;*
- *the size of this interval depends on the seriousness of the threat and on the social cost of public funds employed in financing the subsidy. The stronger the threat and the lower the social cost of public funds, the more likely is the signature of the VA.*

The assumption about a positive difference in costs between the mandatory and the negotiated regime is probably empirically founded but its characterisation as a necessary condition may excessively restrict the relevance of the analysis and make its results quite predictable. In another theoretical work dealing with nonpoint pollution control, Segerson (1998) relaxes this assumption. The consequence is that the existence of an equilibrium voluntary abatement is no longer ensured, being instead contingent on regulator's and firm's payoffs. It is however confirmed that there exists a positive relationship between the severity of the threat, the extent of transaction costs under the mandatory regime and the width of the range of abatement levels which allow for the negotiation to take place. It is also confirmed that the introduction of a subsidy extends the possibility of undertaking a voluntary agreement .

Box 1. Basic formulation of Segerson-Miceli's model

Consider a case in which a regulator maximises the expected net social benefit by offering an abatement level a_V *to one or more polluting firms. Firms decide freely whether or not to sign the agreement: if they accept the offer, unitary costs of abatement* c_V *are lower than if they were to satisfy a legal standard. If they reject the offer, they are faced with a legislative body which (in order to maximise social welfare) can impose a minimum standard* a_L*. In this case firms are faced with unitary costs* C_L*. Legislative intervention happens with a probability* r *, which, for simplicity, is considered independent of the fact that the regulator offers an agreement.*

The first point to be analysed in such a framework is whether VAs are an equilibrium result of the strategic interaction between firms and the regulator. The situation is investigated in depth by first considering the case with only a firm. The conditions which make accepting a VA are then derived from the definition of the payoff functions of the regulator and the firm.

The regulator maximises social welfare. Therefore his payoff is:

$$\underset{a_V}{MAX} \quad W_V(a_V) = B(a_V) - TC_V(a_V)$$

if the voluntary approach takes place, while if a VA is not signed the expected payoff is

$$\mathsf{r}\ W_L(a_L^*) = \mathsf{r}\left[B(a_L^*) - TC_L(a_L^*)\right],$$

where TC *are the transaction costs, B are net benefits and* a_L^* *is the level of abatement by means of which the legislative body maximises social welfare.*

Payoffs for the firm are modelled as the negative of the total costs they incur under the two options: $C_V(a_V)$ *if the agreement is negotiated,* $\mathsf{r}\,C_L(a_L^*)$ *if the legislative option is left open. As a consequence, given an offer of agreement* a_V *by the regulator, the firm will accept this offer if, and only if, the expected cost is lower than that involved in the legislative threat:*

$$C_V(a_V) \le \mathsf{r}\,C_L(a_L^*)$$

For the sake of simplicity, informational constraints are ruled out. Thus the regulator knows the interval $[0, a_V^{\max}]$ *in which the firm accepts the agreement and can verify if some of these values maximise social welfare. Thus it will propose an agreement if, and only if,*

$$W_V(a_V) \ge \mathsf{r}\,W_L(a_L^*)$$

This condition identifies an interval $[a_V^{\min}, a_V^{up}]$*, which makes it preferable for the regulator to undertake an agreement rather than rely on legislative intervention. From the hypothesis that transaction costs are higher under the legislative regime than under negotiation, we have* $[a_V^{\min} < a_L^*]$*. In addition, lower transaction costs imply that* a_V^* *, the negotiated level of abatement by means of which the regulator maximises social welfare, is the first best outcome, given that it allows higher abatement levels with lower marginal costs. Therefore, welfare considerations can be made in this model basically due to the cost structure assumed.*

The strong equilibrium outcome of such a model is that an interval $[a_V^{\min}, a_V^{\max}]$ *exists in which a negotiated agreement will take place provided that* $\mathsf{r} > 0$*. Given perfect information, the regulator will always offer a value* a_V *which is acceptable to the firm (less than* $a_V^{\max}$*). Thus, the negotiation of an agreement is the equilibrium result.*

The probability r *can also affect the level of abatement which is implemented under the voluntary regime. Of course, this can only happen if the optimum level* a_V^* *is not acceptable to the firm. This event occurs if:*

$$a_V^{\min} < a_V^{\max} < a_V^*.$$

Hence, if the legislative intervention becomes more likely, the negotiated agreement is the optimal outcome for higher values of $a_V^{\max}$ *and* $a_V^{\min}$*.*

1.3.1.b A regulator with a private agenda

The assumption of smaller transaction costs in the case of VA can also be relaxed by further changing the scenario considered so far. In particular, the hypothesis of a benevolent welfare maximising regulator can be abandoned by assuming that the regulator has his own private agenda.

This is done by Hansen (1997), which extends the model by Segerson and Miceli.[18] Let us assume that the regulator and the legislator[19] have two different objective functions, with different evaluations of consumers' surplus, firms' profits and environmental goals. These differences can be explained by contrasting political views. Alternatively, a regulatory agency could have special interests consisting, for example, in the saving of its time or of its budget resources, as well as direct benefits coming from the firm to the single members of the agency.

In the presence of a private agenda, it is shown that:

> *an interval of abatement levels for which both parties sign the agreement exists (even if costs to the firm and to the regulator are larger than in the case of legislative intervention), provided that disagreement about policy priorities between the legislator and the regulator is sufficiently strong.*

If the objective functions of the two bodies are quite similar, then an ad hoc hypothesis about costs is required again to explain the successful negotiation of an agreement.

The intuition behind this result is the following. Leaving the decision on the abatement level in the hands of the legislative body, the executive branch could be faced with a situation which is very harmful with respect to the objectives of its own private agenda. Broadly speaking, in this case the legislative threat is also affecting the regulator. Hence, in this situation both bargaining parties have an incentive to pre-empt. Optimality of the negotiated result in this case can be quite problematic. If the "benevolent social planner" is the regulator, the use of negotiated agreements should be encouraged. On the contrary, if it is reasonable to assume that the legislator is more resistant to lobbying activities and that its evaluation reflects the interest of the society in a better way,[20] the implementation of VAs could be socially harmful.

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[18] In Segerson-Miceli (1998) the optimal abatement levels for the legislator and the regulator differ only because of the lower transaction and production costs in case of negotiation and not because of a conflict in their respective goals.

[19] Hansen (1997) refers to public actors respectively as "Government" and "Congress".

In general, this model is able to explain why the use of VAs is often encouraged by the executive branches of the government rather than by the legislative bodies. It remains questionable whether VAs are used because of their efficiency characteristics or as a shortcut to democratic processes.

1.3.1.c Dynamic extensions of the static pre-emption framework

The previous framework looks at pre-emption as a "one shot game", in which both the regulator and the firm maximise their objective functions once and for all. In fact, the relationship between a regulating agency and firms is intrinsically dynamic for a number of reasons. One reason is that the "basic parameters" which define the two actors' payoffs are likely to change over time exogenously. These parameters are consumer's sensitivity to environmental problems on the one hand and pollution abatement costs on the other hand. Another reason is that the parameters defining the extent of the environmental problem change as a result of agents' past actions. On the one hand, the environmental damage is not only determined by the flow of emissions but also (and above all in some cases) by the stock. On the other hand, firms' ability to deal with emission reduction is usually dependent on its stock of "know-how" accumulated through past investments.

In short, a dynamic approach is likely to provide us with additional insights on the use of voluntary approaches as environmental policy tool.

A first point which has been analysed is the time path of voluntary abatement in the presence of a threat of taxation. It is well-known that the optimal setting of a standard is equivalent, in welfare terms, to the imposition of a Pigouvian tax, at least as far as the two polar cases of monopoly and perfect competition are concerned. However, when attention is paid over an investment in voluntary abatement, a crucial difference must be underlined. While an increasing mandatory standard is able, by definition, to ensure a better (physical) environmental performance, increasing taxation on emissions can lead, under given circumstances, to lower voluntary abatement levels. This is what is argued in Farzin-Kort (1998). They analyse the behaviour of the firm by considering a dynamic and competitive framework and focus in particular on the role of the uncertainty of the legislative threat.

Traditionally, one of the arguments in favour of market-based environmental policy instruments is their ability to provide firms with greater incentives to adopt abatement technologies in the long run. From a

[20] This is what Hansen (1997) assumes.

theoretical point of view, the statement that higher emission taxation implies a larger stock of abatement capital was shown in a dynamic model under certainty (Xepapadeas, 1992). However, as shown by Farzin-Kort (1998), the presence of uncertainty may lead to opposite conclusions.

When dealing with "threats" or "promises" by public institutions in a dynamic framework, economic theory has often questioned their "credibility". In particular, in an intertemporal framework, public policies have been studied in the light of the so-called "dynamic inconsistency problem". In Kydland-Prescott (1977) words, a policy is dynamic inconsistent if an optimal action defined at time t is no longer optimal at time T even if no changes in the information set have occurred. Petrakis-Xepapadeas (1998) analyse the regulation of polluting emissions through environmental taxation taking into account the dynamic inconsistency problem. This analysis provides us with some further insights into the role of VAs as regulation offsetting tools. In particular,

VAs may be seen as a pre-commitment tool which solves the dynamic inconsistency problem.

Let us assume that voluntary compliance and setting of the taxation path (the threat in this model) are part of a repeated game which the firm is playing with the government. If the situation is one of perfect information, by choosing its own abatement level the firm knows perfectly what the final tax rate will be. In this setting, Petrakis-Xepapadeas (1998) show that, if the government can pre-commit itself to a fixed tax rate:

- *The optimal time consistent tax rate is always lower than the optimal rate under pre-commitment.*
- *As a consequence, voluntary abatement (or environment innovation) is always higher when there is no pre-commitment.*
- *Welfare is however lower when there is no pre-commitment.*[21]

The conclusion is that if the government cannot credibly pre-commit itself to a given tax rate that will be maintained in the long run, there is a more widespread adoption of VAs but a lower social welfare (at least when social damage is a linear function of total emissions).

[21] In the authors' opinion, this result could be strictly dependent on the linear specification of the damage function employed in the model and be reversed by considering a convex function.

1.3.1.d The multi-firm case

So far, the analysis of the regulation offsetting VAs has not yet considered oligopolistic markets. Hence, even if the papers surveyed provide many useful insights into the role of VAs, and on the conditions that lead to their adoption, both under certain and uncertain regulatory threats, both within a static and a dynamic framework, no considerations can be made on the relationship between market structure, the number of firms in the industry and the adoption of VAs.

Segerson-Miceli (1997) try to fill this gap by considering a duopolistic market and by comparing the result with the single firm case previously presented (Cf. section 1.3.1a).

Two cases are considered. The first case is when an agreement with only one of the two firms is sufficient to pre-empt a legislative intervention.[22] It is shown that at the equilibrium only one firm signs the agreement (there is indeed a strong incentive to free-ride). There are therefore two equilibria in which one of the two firms signs the agreement and pre-empts regulation, whereas the other one free-rides. This result is independent of the firms' cost structure, which can only sometimes allow the identification of the firms which actually negotiate the agreement.

In the second case, pre-emption is certain only if both firms negotiate the agreement. Free-riding problems disappear, but the probability of having an agreement is of course lower. This probability depends particularly on the dispersion of the distribution of firms' costs and on the number of firms.[23] In practice, in order to ensure environmental effectiveness, the regulator has to rely on a higher probability of legislative intervention. From the discussion already carried out on the role of the severity of the threat, we know that a stronger threat makes the adoption of VAs more likely. A situation with a "green oriented" legislator seems, therefore, more in favour of VAs when the agreement is operational only if all firms sign it.

In addition to the probability of the legislative intervention, another tool that increases the power of the threat in a multiple firm case is the possibility of "firm-specific pre-emption". This situation is discussed in Segerson (1998) and consists of the provision of a compulsory intervention in the event that a given

[22] Reliability of this hypothesis could be very controversial. An agreement could not permanently pre-empt legislative intervention because the voluntary approach proves to be insufficient. Otherwise it could be used as a tool to identify a standard of abatement which the not-signing firm could also sustain.

[23] By using the same symbols as in section 1.3.1, the condition that allows the VA to be adopted is: $C_V^i \leq \mathsf{r}\, C_L^i$ for all i.

standard is not reached by some of the firms entering the market. The free-riding problem is of course solved because now pre-emption has become an "excludable good".

The conclusions that the results support are still very preliminary. There are indeed few analytical tools which can be used to deal with a multi-firm case with strategic interactions and direct bargaining between firms and regulator. Nonetheless, the existing results show that:

- *In the multi-firm case, a free-riding problem emerges and this reduces the likelihood of adoption and the effectiveness of VAs.*
- *The free-riding problem can be solved, either by implementing the agreement only when all firms sign it or by designing firm-specific threats.*
- *An increase of the number of firms, i.e. a more competitive market structure, makes the two options outlined above more difficult and therefore is less favourable to the adoption of VAs. As a consequence, a concentrated market structure constitutes an economic environment where VAs can be adopted more easily and effectively.*

1.3.2. Endogenising the severity of the regulatory threat: regulatory capture and pre-emption.

The action of undertaking a VA is only one of the ways in which firms can pre-empt regulatory intervention. As a matter of fact, well-known lobbying activities are probably the most common tool used by firms to achieve that goal. If this is the way the "real world" works and the role of firms is prominent when putting in place a VA, the risk of "cosmetic agreements" of course becomes higher.

The economic literature on VAs has become aware of this point, and special attention has already been devoted to the so-called "regulatory capture" process. It has been noted (Börkey *et al.*, 1998) that for this phenomenon to occur, the regulator must have an interest in it. More precisely, this interest must be, at least partially, in conflict with social objectives, as in the Hansen's framework which was discussed in section 1.3.1.

To discuss the issues of regulatory capture,[24] lobbying activities and their relationship with quality and quantity of Vas, we use, as in the previous section, a basic theoretical framework, derived in this case from Maxwell *et al.* (1998), from which extensions and generalisations can easily be presented and analysed.

[24] A theory of regulatory capture is provided by Stigler (1971); Becker (1983); Recent advances are in Laffont-Tirole (1991).

This model considers in a single framework the use of VAs and of lobbying activities aimed at modifying the level of abatement defined by a public body (the regulator). Broadly speaking, firms are seen as able to set a "policy mix" by means of which to tackle the regulatory threat.

All these issues are analysed in a well defined oligopolistic market where strategic interaction among the actors becomes crucial. The resulting model is quite complex and allows a number of issues to be addressed, particularly as far as the interactions between market structure and VAs are concerned.

In the previous section, a negotiated voluntary abatement level was sufficient to pre-empt a mandatory intervention. This hypothesis is replaced by a more articulated one which allows for stakeholders' intervention if the VA is not considered satisfactory. As a consequence, in choosing whether and how much to voluntarily abate, each firm is faced with the following objectives:

a) to pre-empt stakeholders and (possibly) regulator's intervention;
b) to influence regulator's intervention to its advantage;
c) to deal with competition with other firms.

Firms achieve these objectives sequentially, which implies that the model is framed within a three-stage game. In the first stage n^f identical firms voluntarily choose abatement levels (e_i^V). Firms act non-co-operatively, thus giving rise to a free-riding problem. In the second stage, n^c identical consumers decide whether or not to enter an *influence game*[25] for which the payoff is the definition of a mandatory abatement level e_i^R which is added to the voluntary one. In the third stage, oligopolistic firms play a Cournot game by choosing production levels given the total level of abatement effort determined in the previous stages.[26]

Being a decision made in the first stage, the use of VAs also has implications for the subsequent stages. VAs still represent the strategic variable through which to pre-empt regulation. However, now their features are not aimed at directly satisfying the welfare function of the regulator,[27] but the utility function

[25] The influence game is a lobbying action towards the regulator which is activated by consumers if total costs of lobbying (mainly organisation) are smaller than the expected benefits in terms of stronger mandatory abatement levels. Marginal benefits are supposed to be decreasing and marginal lobbying cost increasing: this allows the firm to eventually offer a VA which makes it unprofitable for consumers to play the influence game. See Maxwell *et al.* (1998) for further references about this topic.

[26] The effects of product differentiation based on the environmental characteristics are not considered in the article, even if the framework of the model is probably sufficiently general to also take account of this aspect.

[27] The expression "welfare function" is probably not very precise when referred to the agenda of a public institution. In these cases the economic literature often make use of the expression "loss function", an objective

of consumers which are responsible, through the influence game, for the regulator moving from its usual objectives.[28] Lobbying activity is considered a costly second best policy by the firm, in which costs are only partially compensated by the outcomes in terms of reduced mandatory abatement. Given that the involvement in the influence game is also costly for stakeholders or consumers and society ends up with lower abatement, the trigger of a "lobbying war" appears as an inefficient outcome with respect to a situation of pre-emption through voluntary abatement. A formal presentation of the model is shown on Box 2.

On the basis of this model, Maxwell *et al*. (1998) show a number of interesting results, which can be summarised as follows:

Positive results:

- *a free riding problem does exist. The dimension of* $Z^V_{\max}$ *is decreasing in the number of firms and it would be higher allowing for the possibility of co-operation. However, this result is crucially dependent on the assumption that no private benefits derive from voluntary abatement. In fact, if we also would have considered an increase of demand as in the green consumerism models, the model could end up with extra investment due to non-co-operative behaviour, like in some general models of entry deterrence in the theory of oligopoly (Gilbert-Vives, 1986).*[29]
- *an increased threat of government regulation, determined by a change of consumer's power, induces firms to increase voluntary reduction of emissions (at least in the interval* $0 < Z^V \leq Z^V_{\max}$*).*
- *rivalry between interest groups produces weaker pollution regulation.*

Normative results

- *When considering the costs of influencing the regulator's policy, social welfare under pre-emption Pareto-dominates social welfare in the case when the influence game is played. In other words, both parties always gain if the influence game is avoided.*[30]

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function consisting of a distance from an optimum which has to be minimised given the subjective weights that the public body gives to its contrasting goals (namely consumer's utility and firms profits in this case).

[28] For the sake of simplicity, it can be assumed that, in the absence of lobbying, the regulator maximises a utilitarian social welfare function, with equal weights given to profits and consumer's surplus.

[29] It is not clear, however, what effects an increase of the number of firms has on the possibility that pre-emption will occur. On one hand, a larger n^f implies that each firm is willing to offer a lower level of voluntary abatement. On the other hand, this could increase the lobbying power of industry by making it less profitable for consumers to enter the influence game. The overall effect is undetermined.

Box 2. Basic formulation of Maxwell et al. (1998) model

We specify the model starting from the third stage because of the usual backward induction structure of dynamic games. The market is characterised by the presence of n^f *identical firms and* n^c *identical consumers, with* $n^f \leq n^c$*. The latter inequality represents a quite general situation and provides a basis to the hypothesis that consumers share higher co-ordination costs than do firms.*

On the supply side, constant marginal costs are assumed. Increasing marginal costs are instead assumed with regard to the adoption of a pollution control input (Z *). On the demand side, consumers' decisions are not affected by the environmental quality of goods. The consequence of these assumptions is that an investment in the pollution control input always decreases firms' profits according to a more than proportional relationship. Thus, in the third stage, competition among firms is exclusively on produced quantities and is not affected by other strategic choices.*

The "influence game" played in the second stage produces a modification of the regulator's choices about the overall level of abatement or (as a consequence) of specific investment Z *that firms must undertake. Given the possibility of a voluntary reduction, we have* $Z = Z^V + Z^M$*, where the superscripts* M *and* V *refer respectively to "mandatory" and "voluntary". Consumers are stakeholders whose objective is identified by a generic indirect utility function like the following one:*

$$U \equiv U\left(P(Z), D(Z)\right) - m,$$

where P *is the price,* D *the total amount of degradation, and* m *is individual lobbying expenditure.*

Similarly to the assumption for firms with respect to pollution control activities, the presence of a fixed cost for consumers in order to be able to carry out lobbying activity is assumed. We have also already seen that firms face increasing marginal costs in abating. At the same time, the positive utility experienced by consumers from abatement displays decreasing marginal returns. Such a dichotomy with respect to marginal abatement ensures the existence of an equilibrium abatement effort level. In addition, both categories of agents act non-co-operatively, by considering as given the action of the other participants to the game. Since the number of consumers is larger than the number of firms, organisation costs by the former are assumed to be the highest. This fact then constitutes the basis by means of which to argue that the influence game ends with a level of mandatory abatement lower than in the case when no lobbying activities are undertaken.

In the first stage, firms decide if and how much to invest in voluntary pollution control with a twofold aim. The first one is the pre-emption of the influence game, consequently renouncing to modify regulator's optimal choices. This is the first best policy for the firm, given that the outcome in terms of reduced regulatory intervention only partially compensates additional costs due to pressure activities.

If pre-emption of consumers cannot be avoided, voluntary abatement is however able to affect the behaviour of the participants in the influence game. In particular, given that consumers marginal utility is decreasing in abatement levels, a higher voluntary pollution control will imply less engagement in trying to influence the mandatory levels. Conversely, due to increasing marginal cost in abating, this strategy will make firms more determined in implementing their lobbying activity

Because of the given characterisation of consumers and firms reaction functions, the outcome in terms of voluntary pollution control and lobbying activity will be dependent on consumer's organisation and influence costs. In particular, three situations can occur:

- Total costs are lower than the additional utility which can be obtained through the influence game given the maximum voluntary abatement level ($Z^V_{\max}$*) that firms are willing to undertake. In this case in equilibrium we have* $Z^V_{\max}$ *and the influence game is played.*

- Total costs are higher than the additional utility which can be obtained through the influence game for some positive voluntary abatement level lower or equal to $Z^V_{\max}$*. In this case in equilibrium we have* $0 < Z^V \leq Z^V_{\max}$ *and the lobbying activity is pre-empted.*

- Total costs are always higher than the additional utility which can be obtained through the influence game. In this case consumer's entry into the political arena is "blocked" and no voluntary abatement takes place.

[30] The fact that the influence game can actually be played indicates that we are in the presence of a prisoner's dilemma-like situation.

- *However, sub-optimal abatement levels due to pre-emption by the VA cannot be ruled out.*
- *Conversely, if the industry has more consumers than firms and consumer's surplus is given at least the same weight as firm's profits is, the political influence game generates less abatement than is socially optimal.*
- *An antitrust policy which allows firms to co-ordinate on voluntary abatement (so-called block exemptions, in legal terms) leads to beneficial self-regulation.*
- *Stake-holders intervention in the political process should not be financed provided that consumers entry in the influence game is not "blocked" by organisational costs which are too high, given that their entrance into the political arena implies a loss of benefits coming from self-regulation.*

As far as our main objective is concerned, that is the analysis of the impact of market structure on VAs, it is clear form the above statements that a more concentrated industry favours the adoption of VAs, because it reduces the significance of the free-riding problem, the organisation costs to be paid by firms, and rivalry on the product market. If firms are allowed to co-operate on the abatement policy, environmental benefits increase. Hence we find again a conclusion which was also derived with previous models (green reputation enhancing models, pre-emption models without regulatory capture): the adoption of VAs is more likely and their effectiveness is increased when the industry is more concentrated, i.e. market structure is less competitive.

This implies that the objectives of environmental policies may be in contrast with the objectives of competition policies and that the two must be closely co-ordinated to achieve a social optimum. The next section will be devoted to a more detailed summary of the policy implications derived from the first part of this survey.

1.4 Policy implications

The literature on the relationship between market structure and voluntary approaches is still quite limited. In particular, the effectiveness and efficiency of VAs when markets are imperfectly competitive are not yet fully explored. This problem is not specific to VAs. All environmental policy instruments are scarcely analysed within imperfectly competitive frameworks despite the fact that, as recently shown in Carraro,

Katsoulacos and Xepapadeas (1996), the results proved under the assumption of perfect competition are quite different from those that can be shown in the case of oligopoly.

This is not surprising, because Buchanan (1969) already showed how different environmental policy analysis could be in the case of monopoly with respect to the case of perfect competition. However, what Carraro, Katsoulacos and Xepapadeas (1996) present in a set of papers is that policy results in oligopoly are often far from being an intermediate case with respect to the polar cases of perfect competition and monopoly. Oligopolistic strategic interactions often give rise to new phenomena that require a careful design of environmental policy and its combination with other policy tools.

This is also true with respect to VAs. Whenever oligopolistic strategic interactions are introduced, the analysis become more complex, a second-best world appears and environmental externalities interact with market inefficiencies. This explains why the literature on VAs and imperfect competition is still quite limited, but this does not prevent us from reaching some conclusions from the papers that have been surveyed. Indeed, there are some results that are quite robust to different model assumptions and to different specifications of why profit-maximising firms decide to undertake a VA.

Indeed whether voluntary emission reduction or control is undertaken:

- because firms want to profit from consumers' environmental sensitivity or want to pre-empt future costly regulation
- under condition of perfect anticipation of future regulation or of uncertainty

and whether firms:

- compete in quantities or prices
- face a market demand derived from a utility function where the marginal effect of abatement effort on consumers' utility is increasing or decreasing

we can say that:

- *a more concentrated industry favours the adoption of VAs*
- *the effectiveness of VAs increases when industry is more concentrated*
- *VAs are even more beneficial if firms are allowed to co-operate on emission reduction (the setting of the VA)*

These results are strongly related, but not exclusively so, to the presence of free-riding incentives that give rise to strategic behaviours which reduce firms' abatement effort. The free-riding incentive can be offset by adequately designing the voluntary agreement, but this optimal design is again easier when industry is more concentrated.

Part 2: From VAs to market structure

2.1. VAs and competition

As said at the beginning of this work, the relationship between VAs and the degree of market concentration is a two-directional one. Indeed, the adoption of VAs can have several effects on market structure. The most intuitive result is that by signing an agreement firms have the opportunity to determine *de facto* a more concentrated structure by defining implicit rules for fixing market prices and quantities. But explicit effects of VAs on market concentration can also be figured out. A VA can play the role of a barrier to entry for new firms that are not necessarily allowed to share the benefits of the VAs (e.g. in terms of reputation effects). Or more simply, a VA adopted by a subset of firms modifies the distribution of costs across firms in the industry thus also modifying industry concentration (Carraro-Soubeyran, 1996a,b)

Specific theoretical literature which deals with the effects of VAs on market concentration and structure has not yet been developed. Therefore, while in the first part we were able to limit our analysis to theoretical contributions regarding market structure and VAs, in this second part we will usually make use of more general branches of oligopoly theory which seem to offer promising insights for our topic.

In the following, we will consider two features of VAs that certainly feed back on market structure:

- on the one hand, VAs increase a firm's costs (even if these costs may increase even more within other regulatory frameworks);
- on the other hand, VAs provide incentives and a discussion table which are likely to affect the possibility of collusive behaviour;
- finally, VAs modify the barriers to entry in the industry and as a consequence affect industry concentration.

The sequel of this second part of this survey will try to analyse the sign of these effects, namely whether the implementation of a VA in a given industry will increase or reduce market concentration. To do that we will draw on several theoretical contributions which are not environment-specific but that can be used to derive sound conclusions about the effects of VAs on market structure.

2.2. Cost approach

As said, one way of looking at the effects of VAs on market structure is to identify the implications of VAs for firms' costs. It is clear that the adoption of a voluntary abatement strategy increases firms' costs. We know from the previous section that this increase is lower than the increase of revenue – in the case of green reputation enhancing VAs – or lower than the increase of costs if other forms of regulation are introduced – in the case of regulation offsetting VAs. Nonetheless there is an increase of costs and this feeds back on market structure.

The relationship between a change of the industry cost structure and industry concentration has been analysed by Dung (1993) and in the case of environmental policy by Carraro and Soubeyran (1996a). If we exclude the case of a perfectly inelastic demand function in which cost increases are completely transferred to consumers, we can use this literature to discuss the effect of VAs on industry concentration.

Consider first the case of green reputation enhancing VAs. In this case, not only do costs increase but also profits. Carraro and Soubeyran (1996a) show that:

- *provided that* $Q > Q^*$*, a threshold market share* s^* *exists which identifies which firms increase their profits due to undertaking a VA. Namely, firms whose market share is lower than* s^* *increase their profits;*
- *at least one firm increases profits when costs increase.*

This first result helps us to understand why only a subset of firms may decide to sign the VA (of course this particular type of VA) and to identify these firms as those which need to increase their market share more than the others. However, the more the market is symmetric, the larger is the number of firms which have a market share s_i smaller than s^*, so that a situation in which all firms have an incentive to negotiate an agreement is possible.

VAs can also be signed to pre-empt more stringent regulation. In this case, profits may decrease, even if less than otherwise, and a more general conclusion can be achieved. It is in fact possible to show that:

The same critical value Q^* *determines whether industry concentration, as measured by the Herfindahl index* $\sum_i s_i^2$*, is increasing (*$Q < Q^*$*) or decreasing (*$Q > Q^*$*).*

Hence, market concentration increases for low production levels. These results are further confirmed by a second paper by Carraro and Soubeyran (1996b) where returns to scale are non-increasing, emissions are weakly convex in total output and a more general demand structure (with emission levels as an argument) is considered. Moreover, this paper specifically addresses the case where only some of the firms are faced with an increase in production costs.

In this case a first important result is shown:

> *When one or more firms increase their costs, reaction functions become less steep, i.e. interdependency among firms increases.*

Hence, this would suggest that the market becomes more competitive and that collusive agreements are less likely. However, what happens to industry concentration?

> *Industry concentration, as measured by the Herfindahl index, increases when costs increase, even when cost increases are firm-specific, provided that the industry is already sufficiently concentrated*

This result is quite important because it states that a VA can increase industry concentration if applied in an already concentrated industry. But, as seen in Part 1, VAs are more likely to be introduced in concentrated industries. Hence:

> *the introduction of VAs in a concentrated industry can further increase concentration thus having perverse effects on the government's competition objectives*

This conclusion is based on a particular effect of VAs -- as well of other environmental regulations -- i.e. cost increase. In the next sections we will analyse the effects on industry concentration of other factors which are influenced by VAs.

2.3. VAs and factors which influence market structure

In this section we would like to identify other factors that in oligopoly theory usually affect industry concentration and then relate these factors to the presence of VAs. In general oligopoly theory, market concentration is seen to depend mainly on three factors, namely industry dynamics, collusion possibilities, and the existence of barriers to entry.

The main lessons which can be learned from this literature are:

- increased industry dynamics reduces concentration;
- increased collusion increases market concentration;
- the presence of barriers to entry favour industry concentration.

Indeed, these three aspects are strongly related each other. For example, it is clear that collusion among firms is more likely to take place when there is concern for future gains and losses, rather than in a static framework in which agents can hope to exploit a sort of "first move" advantage without being worried about competitors' reactions. The following sections are respectively devoted to the analysis of the use of VAs in a dynamic framework and their use as a means to affect entry in the market.

2.3.1 Aspects of industry dynamics. Repeated interaction and supergames

When representing dynamics in a strategic environment, one of the main challenges is the characterisation of repeated interaction among economic agents. The common tool used is the "supergame", basically a repetition of a static game for an infinite or indeterminate number of times in which future pay-offs are weighted with a discount factor. The latter is used to take into account the different importance that agents can assign to the future and is based on the market interest rate or on a "subjective" intertemporal discount rate.

Repeated interaction has proven to be a suitable analytical tool by means of which to originate tacit collusion and the generation of monopoly profits to be modelled, even in a context of competition on prices *à la* Bertrand, provided that (i) firms face an infinite or indeterminate horizon[31]; (ii) they care enough about their own future gains. A brief introduction to supergames is provided in Box 3.[32]

[31] This condition is required in order to obtain a Sub-game Perfect Nash Equilibrium with positive profits. Indeed, an infinity of profits levels spanning between the perfect competition (zero) level and the monopoly (or perfectly collusive) case constitute a SPNE. This result is usually known as the "folk theorem" (see, e.g., Tirole, 1988).

[32] For an extensive treatment of repeated games, see Fudenberg-Tirole (1991), chapter 5.

Box 3. An introduction to supergames

In its simplest form, a supergame works in the following way. For sake of simplicity, let us consider a duopoly. In each period two identical firms split the market, so that firm i *earns* $\Pi^m/2$*, i.e. half of the monopoly profits. The firm discounts the future, so that the present value of its profits will be:*

$$P = \frac{\Pi^m}{2} + \delta\frac{\Pi^m}{2} + \delta^2\frac{\Pi^m}{2} + ... + \delta^t\frac{\Pi^m}{2} + ... + \delta^\infty\frac{\Pi^m}{2} = \frac{\Pi^m}{2(1-\delta)}$$

where $\delta = 1/(1+r)$ *represents the subjective discount factor of future gains by firms and a well-known rule of geometric series has been used. For simplicity it is assumed that the discount factor is the same for both firms.*

In each period, each firm could slightly decrease its price, thus earning approximately Π^m *for one period. In subsequent periods (if the reaction of competitors is immediate) its earnings would be zero given that the other firm would fix a price equal to marginal costs which are assumed constant. Hence, firms will maintain a collusive behaviour provided that*

$$\frac{\Pi^m}{2(1-\delta)} \geq \Pi^m,$$

or, in order to make the variables which determine profits explicit,

$$\frac{x_m(p_m - c)}{2(1-\delta)} \geq x_m(p_m - c).$$

where x_m *and* p_m *are, respectively, monopoly quantity and price.*

This equation implies the condition $\delta \geq 1/2$ *on the discount factor. If we had considered the* n*-firm case, the critical value obtained would have been* $\delta \geq (n-1)/n$*. In words, the larger the number of firms, the lower the intertemporal rate of discount* r *has to be. In other words, this means that agents must give a relatively higher weight to the future.*

Tacit collusive equilibria are usually reached by assuming that firms follow some "trigger strategies" in the presence of an "anticollusive" behaviour by the competitors. Before carrying out any action, firms must therefore take the future reactions of their competitors into account. What threatens to happen is actually a "price war" which destroys the possibility of profits at the industry level. The simplest trigger strategy states that the firm will maintain the monopoly price p^m at time t if other firms did the same in the

previous period and that it will fix the price at the marginal cost c from period t to infinity if competitors previously decreased the price.

The simplicity of this strategy, often labelled as the "Nash Reversion Strategy" [33], derives from the infinite number of periods of punishment which follows the rupture of the collusion. Of course more elaborated schemes of triggers can be conceived, mainly dependent on the nature of the market considered.[34] However, in order to comment on the introduction of a policy instrument based on voluntary compliance, this elementary framework can be retained.

The basic questions which we aim to answer are:

- what are the likely collusive effects of the use of VAs when firms interact repeatedly?
- should we expect more or less price wars due to the use of VAs?

In order to investigate the relationship between VAs and repeated interaction, we distinguish as usual between the reputation enhancing and the regulatory gain motive.

In the case of reputation enhancing VAs, we can again use the results derived in Carraro-Soubeyran (1996a,b) where it is shown that a cost increase due to voluntary abatement reduces overall output and increases market price. Extending this result to the case in which firms adopt price strategies, the simple introduction of new market values on the left and on the right hand side of $\frac{x_m(p_m - c)}{2(1-\delta)} \geq x_m(p_m - c)$ does not change the collusion condition $\delta \geq 1/2$. Present advantages and future disadvantages from anticollusive behaviour decrease by the same amount. Hence, if costs and advantages are distributed in the market according to the same time path, no significant differences appear with respect to a static case.

To make a dynamic model interesting, we must therefore introduce some additional hypotheses like the following ones:

- Market demand evolves exogenously over time.
- Different effects of VAs on firms' performance are distributed progressively in time. These effects take the form of:

[33] For example Mas-Colell, Whinston and Green (1995).

[34] See, for example, Green-Porter, (1984).

1) progressive demand increase due to gradual awareness by consumers of environmental quality improvement.

2) unitary costs decrease over time (for example because VAs enhance innovation processes).

In order to analyse the case of evolving demand, let us imagine a constant rate of growth g and express the demand at time t as x^{gt}. In this case the equivalent of the collusion condition $\frac{x_m(p_m - c)}{2(1-d)} \geq x_m(p_m - c)$ is

$$\frac{x_m^{gt}(p_m - c)}{2(1-dx_m)} \geq x_m^{gt}(p_m - c),$$

from which the condition for the sustainability of the collusion becomes $d \geq 1/2x_m$.

Hence:

- *if VAs increase costs and reduce industry output, i.e.* $x_{VA} < x_m$*, the adoption of VAs makes a collusive equilibrium more difficult in the presence of a (permanent) exogeneous boom, while it makes it easier in the presence of a (permanent) recession;*[35]
- *conversely, if VAs positively affect the rate of growth* g *(for example, due to the progressive diffusion of the effects of green consumerism) in a situation previously characterised by a constant demand, then VAs make it easier to achieve collusive equilibria (compare the condition* $d \geq 1/2$ *with the condition* $d \geq 1/2x_{VA}$ *for* $x_{VA} > 1$*).*

The intuition behind both propositions is quite straightforward. In the first case, when demand is growing over time, collusion is more likely because firms fear to loose their future "piece of cake" which is becoming greater and greater. The adoption of a VA (which implies a reduction of total market output if abatement is costly) lessens collusion advantages because it rescales attainable profits in each one of the future periods. On the contrary, when the VA causes diluted positive effects on demand, collusion becomes stronger precisely because of the prospect for larger industry profits arising from co-operation in the future. An analogous consideration could be made with regard to the case of unitary costs decrease over time.

Using the theory of supergames we are also able to provide additional insights in those cases in which VAs are mainly used to pre-empt a regulatory intervention. As usual, let us suppose profits to be $P^m/2$ for firm

[35] This is exactly the result obtained in Rothemberg-Saloner (1986) when considering a more general model with fluctuating demand.

i when no regulatory intervention takes place. In addition, we assume that the severity of the regulatory threat (represented by the probability of the regulator's intervention) is $1-a$ in each period, with $0 \le a \le 1$.[36] Once the regulatory action takes place, it is maintained forever.

In Box 4 it is shown that in this case the tacit collusion condition becomes $d \ge 1/2a$. This simple condition allows us to state that:

- *the existence of a regulatory threat makes collusion among firms more difficult*
- *conversely, the use of a VA aimed at pre-empting* ($a = 1$)*, or lessening (a new threat* $1-b < 1-a$ *) a regulatory threat, gives more room for collusive strategies among firms.*

Box 4. Repeated interaction in the case of regulatory threat

Assume that the probability of the regulator's intervention is $1-a$ *in each period, with* $0 \le a \le 1$ *and that, in the presence of a regulatory intervention, firm's profits become smaller. Say therefore that:* $P^R/2 < P^m/2$.

Given this situation, the expected profits for the firm at time 1 *are*

$$P^E = aP^m/2 + (1-a)P^R/2$$

To make computation easier, let us rescale profits under the two events so as to have $\tilde{P}^m = P^m - P^R$ *and* $\tilde{P}^R = P^R - P^R = 0$. *In this way, the previous condition becomes:*

$$\tilde{P}^E = a\tilde{P}^m/2$$

At time 2, keeping the regulatory threat constant, expected profits will be $aa\tilde{P}^m/2$, *and so on for subsequent periods. In practice, an additional discount rate is applied to future profits equal to the probability of escaping regulation. By considering an infinite horizon the inequality which makes it profitable to collude therefore becomes:*

$$P = \frac{\tilde{P}^m}{2} + ad\frac{\tilde{P}^m}{2} + a^2d^2\frac{\tilde{P}^m}{2} + ... + a^\infty d^\infty \frac{\tilde{P}^m}{2} = \frac{\tilde{P}^m}{2(1-ad)} \ge \tilde{P}^m$$

from which the condition on the discount factor becomes:

$$d \ge 1/2a\,.$$

Finally note that the simple formulation chosen would allow us to summarise both reputation enhancing and regulatory gains effects in a single condition. By combining the previous conditions, we would get

$$\frac{x_m^g(p_m - c)}{2(1-adx_m)} \ge x_m^g(p_m - c),$$

from which the tacit collusion condition becomes

$$d \ge 1/2ax_m$$

[36] We express the severity of the regulatory threat in a different way with respect to part 1 for ease of computation.

Also in this case the results are quite intuitive. The presence of a regulatory threat acts as an additional discount factor of future gains, while leaving unaffected the possibilities of "one shot" monopoly gains with anti-collusive behaviour. The expected return of collusion therefore becomes less convenient. Conversely, by pre-empting the regulatory intervention, future profits become less uncertain for firms, which consequently assign them a smaller discount rate and become more "patient".

To summarise, in a dynamic context characterised by repeated interaction, VAs appear as a powerful tool through which firms are able to affect the possibility of a collusive equilibrium at the industry level. The statement that VAs increase collusion is in particular valid whenever it is assumed that they cause a progressive positive demand effect, a diluted reduction in abatement costs due to innovation or a reduction of the threat of regulation.

2.3.2 Barriers to entry and exclusion strategies

Up to now, we have always considered the number of firms entering the market as given. However, market structure is not only affected by the variation in demand shares in the hands of existing companies or by the possibility of enhancing collusion strategies, but also (perhaps even principally) by new competitors' entry into the market. This is why in Part 1, we focused our attention mainly on the number of firms in the industry and on industry concentration. This is also why it is important to discuss the possibility that VAs constitute an additional barrier for firms to enter the industry in which the VA has been signed.

A great deal of literature on barriers to entry has been developed since the first studies by Bain (1956). These barriers can simply reflect the nature of production or demand in an industry or can be the outcome of a precise strategy of incumbent firms aimed at preserving their monopoly rents. Of course, given the "voluntary" nature of the policy instruments which we are analysing, we are mainly interested in the latter type of barriers.

In particular, in this section we will try to assess:

- to what extent VAs could be used as a strategic barrier to entry by incumbent firms.
- when entry is ineluctable or even desirable, to what extent can VAs be used to influence the behaviour of entrant firms.

In his seminal work, Bain (1956) identified four elements of market structure which affect new entries:

a) The existence of economies of scale, due, for example, to the necessity of relevant fixed or sunk costs.

b) Unrecoverable absolute cost advantages.

c) Advantages arising from product differentiation.

d) Imperfections in capital markets which are reluctant to finance new enterprises.

By means of modern industrial organisation theory, at least the first three types of barriers can be seen as partially determined by firms' strategies. Among these strategies, we will investigate if there is room for the use of VAs. By changing the perspective used so far in our paper, the effects of VAs adoption by a firm on its competitors are no longer considered to be by-product of actions primarily aimed at exploiting consumer willingness to pay for "greener" commodities or at pre-empting regulation, but one of the prominent motives which drives firms to use them.

As an instrument for this analysis, we will basically use the terminology and formal framework from the work by Fudenberg-Tirole (1984) and Bulow, Geanakoplos and Klemperer (1985). This framework is quite general and allows us to analyse the behaviour of the firm not only when its objective is deter entry, but also when it is aimed at increasing the number of actors in the market. In the latter case we will talk of "accommodated" entry.

Let us consider a two firm case. Firm 1 is already operating in a market and has at its disposal a "weapon" which affects its own and firm 2's (still outside the market) profit expectations. We label this instrument as K_1 and we can think of it as an investment in production capacity, as advertising, R&D, or a VA. As we have learnt in the previous sections, profits can be affected by enlarging market demand, by increasing product differentiation, by changing the probability of a regulatory intervention, by inducing an innovation process, and by modifying collusion conditions.

It is important to notice that the effects of the use of K_1 by firm 1 on firm 2's profits can be decomposed into two parts. On the one hand, a "direct" effect exists which is not related to variations in the optimal supply of firm 1. On the other hand, there is an "indirect" or "strategic" effect which is determined by such variation.

As a first example, let us consider again the framework by Carraro-Soubeyran (1996b) with Cournot competition and demand effects due to emission reduction. If this is the case, we know that in the presence of emission abatement by firm 1 there will be an increase in total demand and a decrease in its own

equilibrium output (an increase for firm 2 because of strategic substitutability). By looking at firm 2, the increase of total demand causes the direct effect while the decrease of firm 1 supply (increase for firm 2) determines the indirect effect.

As a second example, let us think of K_1 as a VA which reduces the regulatory threat for all firms. In this case the direct effect is represented by the increase in the expected profits of firm 2 while keeping constant its output, whereas the indirect effect derives from the reaction to the supply variation by firm 1. If the latter reduces its equilibrium supply and the two firms are strategic complements, this would cause a further increase in firm 2's profits (firms are moving towards monopoly equilibrium quantities and prices).

For the sake of simplicity, we will only consider the strategic effects from now on. The examples just given show that what matters is first of all the nature of the instrument labelled with K_1. Following the terminology used in Tirole (1988) and Gilbert (1989), we define firm 1 as "tough" if profits of firm 2 decrease due to an increase of K_1. We say that the firm is characterised as "soft" if the reverse is true.[37]

The analysis made so far has allowed us to understand how a VA could be used as a strategic barrier (or incentive) to entry. However, this type of behaviour has to be considered not as a goal but as means to achieve higher profits. Therefore, the decision concerning how much to invest is, firstly, dependent on the effects of K_1 on firm 1's profits. In this respect, even the decision whether to deter or to accommodate entry is partially a consequence of that.

In Box 5 an analytical identification is provided of market characteristics which determine the effects of an investment by a firm on its own profits. From an intuitive point of view (and thinking again of previous examples) we conclude that the choice of the optimal investment is contingent to:

- *the nature of competition among firms*, as represented by the sign of the slope of reaction functions (which indicates if firms are "strategic substitutes" or "complements");
- *the nature of the investment* (which makes firm 1"tough" or "soft").

[37] For example, an extended advertising campaign for a brand is likely to characterise the incumbent as tough, given that it is principally aimed at "stealing" customers to possible competitors, whereas a campaign in favour of a general category of goods, being aimed at increasing the market, is likely to characterise the firm as soft.

Box 5. Decomposition of the effects of an investment in an oligopolistic market.

a) Investments as a strategic barrier to entry

To study the use of K_1 *as a tool to affect firm 2's decisions, let us define its profits as a function of* K_1 *and of the "Nash equilibrium" production levels of the two firms* x_1^* *and* x_2^**, i.e.*

$$\Pi^2 \equiv \Pi^2\left(K_1, x_1^*(K_1), x_2^*(K_1)\right) \ .$$

Depending on the sign of Π^2 *subsequent to the undertaking of* K_1 *we are able to say whether firm 1 is deterring or accommodating the entry. By computing a total derivative, from previous definition it is also possible to study the effects of a variation of* K_1 *on the profits of the "entrant".*

$$\frac{d\Pi^2}{dK_1} = \frac{\partial \Pi^2}{\partial K_1} + \frac{\partial \Pi^2}{\partial x_1}\frac{dx_1^*}{dK_1} + \frac{\partial \Pi^2}{\partial x_2}\frac{dx_2^*}{dK_1} \ .$$

This formula reduces to

$$\frac{d\Pi^2}{dK_1} = \frac{\partial \Pi^2}{\partial K_1} + \frac{\partial \Pi^2}{\partial x_1}\frac{dx_1^*}{dK_1}$$

given that the profit maximisation condition implies that the term $\partial \Pi^i / \partial x_i$ *is equal to zero,*[38] *and represents the basis for the interpretation of the incumbent firm's behaviour.*

The first term on the right hand side of the equation represents the "direct" effect of the variation in K_1 *on the entrant's profit expectations, in the sense that it is not related to variations in the optimal supply of firm 1. This happens, instead, in the second term of the right hand side (where the differential* dx_1^* / dK_1 *appears) and which constitutes the "strategic" or "indirect" effect. Firm 1 is defined "tough" if* $d\Pi^2 / dK_1 < 0$ *and "soft" if the reverse is true For the sake of simplicity, we will only consider the strategic effects from now on.*

b) Determination of the optimal investment in an oligopolistic market

The total derivative for firm 1 becomes:

$$\frac{d\Pi^1}{dK_1} = \frac{\partial \Pi^1}{\partial K_1} + \frac{\partial \Pi^1}{\partial x_2}\frac{dx_2^*}{dK_1}$$

As said before, we do not consider the direct effect, which would take place even in the absence of other competitors. In order to derive a rule for the optimal action of firm 2, we can rewrite the last differential on the RHS as $\frac{dx_2^*}{dK_1} = \frac{dx_2^*}{dx_1}\frac{dx_1^*}{dK_1} = R_2'\left(x_1^*\right)\frac{dx_1^*}{dK_1}$*, where* $R_2'\left(x_1^*\right)$ *is the derivative of the reaction function which characterises firms as strategic complements or substitutes. We can therefore conclude (by exploiting the symmetry* $d\Pi^1 / dx_2 = d\Pi^2 / dx_1$ *) that:*

$$sign\frac{d\Pi^1}{dK_1} \approx sign\left(\frac{\partial \Pi^1}{\partial x_2}\frac{dx_2^*}{dK_1}\right) = sign\left(\frac{\partial \Pi^2}{\partial x_1}\frac{dx_1^*}{dK_1}\right) \times sign\left(R_2'\right)$$

From last equation the choice of the optimal investment is contingent to the nature of competition among firms (i.e. if they are strategic substitutes or complements) and to the nature of the investment (which makes firm 1"tough" or "soft").

The nature of competition provides firm 1 with an indication of (broadly) whether to induce an enlargement or a reduction of firm 2's production. The nature of the investment indicates how to reach the objective

[38] Analytical proof of this point involves the use of the so-called envelop theorem.

indicated by the nature of competition. Additional considerations determined by the dimension of direct effects and by the comparison of final profits in the presence and in the absence of the competitor determines if the firm aims at deterring or accommodating entry.[39]

Various combinations of the sign of reaction functions and the different types of investment lead to four different kinds of firm behaviour. Using Fudenberg-Tirole's (1984) original terminology they are:

1) The "top dog" strategy. The incumbent firm undertakes a large investment in K_1 *which makes it "tough" with respect to its competitors (*$d\Pi^2/dK_1 < 0$*).* We should observe this strategy whenever firm 1 wants to deter entry and also when it finds it profitable to accommodate (this case is limited to the situation in which firms' strategies are strategic substitutes).

2) The "fat cat" strategy. The incumbent firm undertakes a large investment in K_1 *which makes it "soft" (*$d\Pi^2/dK_1 > 0$*).* We expect this strategy whenever entry is accommodated and firms' strategies are strategic complements.

3) The "puppy dog" strategy. The incumbent firm underinvests in K_1*, which again characterises it as tough, in order not to damage firm 2.* This behaviour occurs when entry is accommodated and firms' strategies are strategic complements.

4) The "lean and hungry look" strategy. The incumbent firm underinvests in K_1*, which makes it soft, to hinder the expansion of its own competitors.* This strategy is expected whenever the firm wants to deter entry and the nature of its investment is "soft". In the case of accommodated entry, it is the optimal strategy provided that we are in the presence of a soft investment nature and firms' strategies are strategic substitutes.

Summing up:

	Accommodated entry		Deterred entry	
Nature of K_1	*tough* ($d\Pi^i/dK_j < 0$)	*Soft* ($d\Pi^i/dK_j > 0$)	*Tough*	*Soft*
$R_i' > 0$	Puppy dog	Fat cat	Top dog	Lean and hungry
$R_i' < 0$	Top dog	Lean and hungry	Top dog	Lean and hungry

[39] We can not be more precise because we would have to define the pay-offs and the number of stages of the game exactly. It could be a situation with three stages: investment, entry of firm 2, competition. Conversely, the entry of firm 2 might not be under the control of the incumbent, and only two stages should then be considered. We do not specify all of this in order to be able to define a general typology like the following.

Fudenberg and Tirole's (1984) taxonomy is very general and underlines the fact, often misconceived, that a firm may not only deter the entry of a competitor but, once it considers entry desirable or inevitable, may also affect the behaviour of such a firm by means of a few strategic actions. Let us therefore use this taxonomy to analyse the effects of VAs on market structure

As a first example, consider the case of accommodating strategies, namely the case of a VA aimed at enhancing the "green reputation" of a product. If the effects concern principally total demand, firms which undertake the VA are characterised as "soft". When firms are strategic complements, a single company will find it convenient to adopt a voluntary approach even (and especially) if by doing so it gives advantages to the other firm. In this case the implementation of a VA represents the "fat cat strategy". The opposite is true when firms, by competing *à la* Cournot, are strategic complements. This is the case in Carraro and Soubeyran (1996a, 1996b) as well as Garvie's (1997) article, where the presence of free riding is actually stressed. Underinvestment due to free riding is actually the "lean and hungry look strategy".

Consider, instead, a case of deterred entry. An example could be when an additional voluntary abatement level is reached through large R&D investments or by building a new large plant. This case could actually resemble the creation of a barrier to entry in terms of economies of scale or of absolute cost advantages. In both cases, it is likely that the investment has determined a high minimum efficient scale which makes a high production level profitable. The firm is therefore using a "top dog" strategy which, in the presence of a "tough investment", is optimal whenever it wants to deter entry.

A particular case of "Top Dog" strategy aimed at deterring entry is when, through voluntary overcompliance, firms try to induce future stronger regulation which prevents entry of new firms (Barrett, 1991; Salop-Scheffman, 1983). In this case the incumbent firm is "tough" because the regulation or even the threat of it reduces expected profits of the entrant.[40]

One of the barriers to entry classified by Bain is represented by product differentiation. We have also seen in the first part of this survey, through the paper by Arora-Gangopadyay (1995), that VAs can be used by firms to differentiate themselves from each other according to the level of their environmental performance. In this context, it is possible to think of the strategic use of VAs both in a case in which entry is deterred and when it is accommodated. In particular, in comparison with a benchmark case which could be represented by that described by Arora and Gangopadyay, we should expect an underinvestment in

[40] This case resembles the so-called "Porter hypothesis" (Porter, 1990, 1991) where, however, the positive aspects of this behaviour are pointed out. In Porter's view, by adopting higher environmental standards firms can secure a competitive advantage because they are induced to cost reductions and innovation.

cleaning-up activities (to maintain product differentiation) by the "dirtiest" firm, which therefore would act as a "puppy dog", when entry is accommodated.

Conversely, when entry is deterred, the use of VAs aimed at capturing willingness to pay for green consumerism can lead to strategic overinvestment by the incumbent. We know, indeed, that when firms compete in prices (more in general when they are strategic complements), the optimal strategy is the "top dog" behaviour, which in this case results in satisfying the preferences of the richest people through a more environment-friendly production and in leaving dirtier and less profitable production to the entrant firm.

A barrier to entry related to product differentiation is the "brand proliferation" phenomenon, when the same company tries to fill-in the market by occupying the largest possible number of market niches.[41] In our case, we can think of a firm or of an industry association which, by means of a VA, enters the market with a new "clean" product while continuing to produce an old (and "dirty") similar good. By doing so, the incumbent firm or cartel is deterring entry given that it is limiting the maximum distance in the space of the environmental characteristics (and, as a consequence, the amount of profit) which the entrant could obtain. Of course, this situation becomes possible provided that we assume that the incumbent has "the advantage of the first move".

However, why should a firm, in a given period of time, decide to adopt this "top dog" strategy? After all, the niche should already be occupied, if it were profitable to do so. A possible answer is that the market is growing permanently, so that the production of some varieties of goods only becomes profitable after a given period. Arora-Gangopadyay's (1995) idea that willingness to pay for environmental characteristics grows with personal income is adapted perfectly to this case. An alternative explanation could be represented by the incentives which a firm receives when it accepts to adopt a VA. In fact, it is very unlikely that a public body would offer some advantages to a firm which is not yet present in a given market. If that were the case, public policy would be involuntarily financing the creation of a strategic barrier to entry against some firms which could have been ready to adopt a clean production process on their own.

Being aware of the fact that firms can bias the usual level of their investments in order to deter or to accommodate entry, it becomes possible to identify some possibilities for policy intervention. Think, for example, of a situation similar to the first one we discussed, with an industrial sector in which firms compete in quantities. If this is the case, we know from our taxonomy that firms will follow the "lean and hungry look" strategy, i.e. they will underinvest in voluntary abatement in order to avoid an increase in the

equilibrium production level of the competitors. In other words, this is the case in which free riding problems are particularly relevant. The negotiation of an agreement which would lead to co-ordinated solutions would ensure in this case that an effective level of voluntary abatement takes place.

Let us summarise the main findings of this section. First, note how the non-compulsory nature of VAs is likely to facilitate their strategic use. Nearly all the strategies introduced in Fudenberg-Tirole (1984) can be thought to occur when VAs are used. Second, most of these strategic use of VAs are directed either at deterring the entry of new firms in the industry or at making them less profitable. Hence, the effect on industry concentration is straightforward. Sooner or later, industry concentration is going to increase.

The conclusion is therefore similar to the one already reached in sections 2.2 and 2.3. The adoption of VAs may increase industry concentration and competition, thus inducing economic costs that partly offsets the environmental benefits produced by firms' voluntary emission abatement.

Conclusions

This paper has surveyed the recent literature devoted to the analysis of the interactions between market structure and the adoption of voluntary or negotiated agreements as a tool of environmental policy. The goal of this survey was twofold. On the one hand, we tried to identify the market environment which is most favourable to the adoption of VAs, namely whether these are more likely to be signed within industries that are more or less concentrated. On the other hand, we aimed at assessing the effects of VAs on market structure and industry concentration.

Even if an environment-specific literature is still in its infancy, we could achieve some robust conclusions by using a series of results developed in general oligopoly theory that could be adapted to the analysis of the issues tackled in this paper. The main conclusions can be stated as follows. As far as the first causality direction is concerned (from market structure to VAs), we find that:

- *a more concentrated industry favours the adoption of VAs*
- *the effectiveness of VAs increases when industry is more concentrated*
- *VAs are even more beneficial if firms are allowed to co-operate on emission reduction (the setting of the VA)*

[41] This case has been studied by Fudemberg-Tirole (1985) and is also discussed in Tirole (1988).

When the focus is on the opposite causality direction, namely from VAs to market structure, we find that:

- *VAs are likely to increase industry concentration by modifying the distribution of costs across the industry*
- *VAs reduce market competition by favouring the adoption of collusive behaviour in the industry*
- *VAs increase industry concentration by providing firms with a strategic variable that can be used to create barriers to entry or to damage new firms that want to enter the industry.*

Hence, our findings suggest that the signature of VAs is favoured by a more concentrated situation and that the adoption of VAs is likely to further increase industry concentration. This creates a sort of vicious circle that may raise some relevant economic costs in terms of reduced consumers' surplus. Reduced competition and increased industry concentration may indeed imply higher market prices and reduced output. This clearly raises a:

- *trade-off between environmental benefits and economic costs provided by the adoption of voluntary approaches*

Moreover, a conflict between environmental policies and competition policies may occur. Indeed, the two policies may have conflicting objectives if the adoption of VAs and the consequent environmental benefits are associated with reduced competition within the industry.

Nonetheless, it is important to stress that this conclusion is still preliminary. Not only because further, and more specific, theoretical investigations are necessary, but also because it is important to quantify the relevance of the two effects identified in this paper. Whereas on the one hand the environmental benefits are clearly identified within a VA, the economic costs are more difficult to assess and require empirical investigations that have not been carried out so far.

The analysis of this paper can therefore be considered as a first step towards a more comprehensive assessment of the relationship between VAs and market structure, but nevertheless an important one, because it suggests that regulators should at least be cautious before extensively using VAs as a tool of environmental policy.

A final remark is also important. Most of the effects highlighted in this are not VA-specific, because trade-offs similar to those identified in this paper also arise when other environmental policy instruments, e.g. eco-taxes, are used under conditions of market imperfections (see Carraro, Katsoulacos and Xepapadeas, 1996). Hence, the solution is not to get rid of VAs in favour of other instruments, but to carefully assess the pros and cons of different policy tools and, above all, to adopt the suitable policy mix that can control both the emission and the competition problems.

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